A SAM Proxy Model for Optimization of Hybrid Solar-Gas Power Generation

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Motivation

- Hybridizing solar-thermal and natural-gas power generation brings the opportunity to exploit the advantages of both systems

- Allowing for flexible operations of each system has the potential to increase the overall system efficiency and economic performance

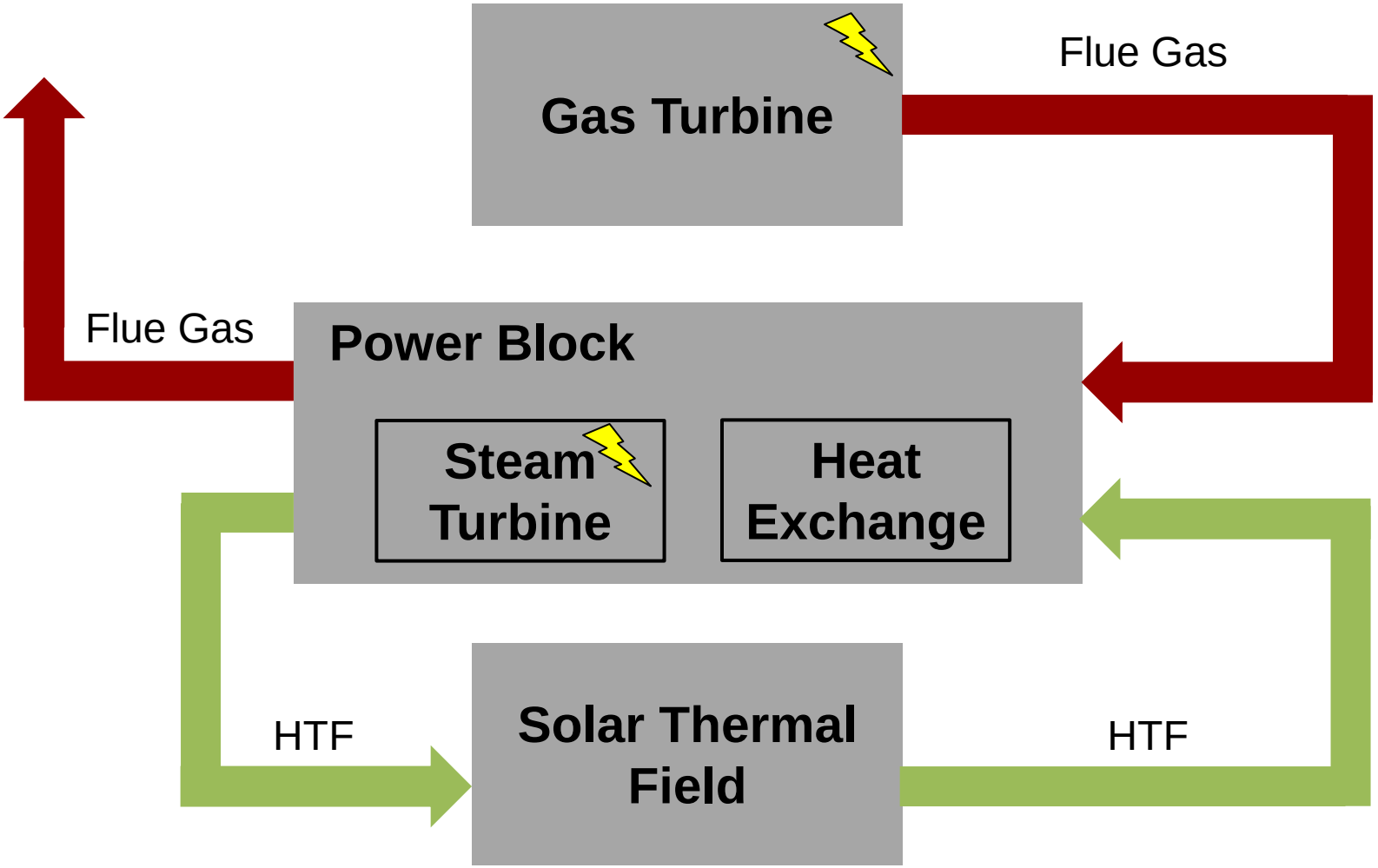
Outline

- Hybrid system overview
- SAM proxy model
  - Model description
  - Comparison of physical and empirical models
- Preliminary results

Hybrid System Overview

- Three main system components:
  - Gas turbine
  - Solar thermal system
  - Power block
- The integration has been designed in a modular fashion, to allow for the exploration of multiple types of systems

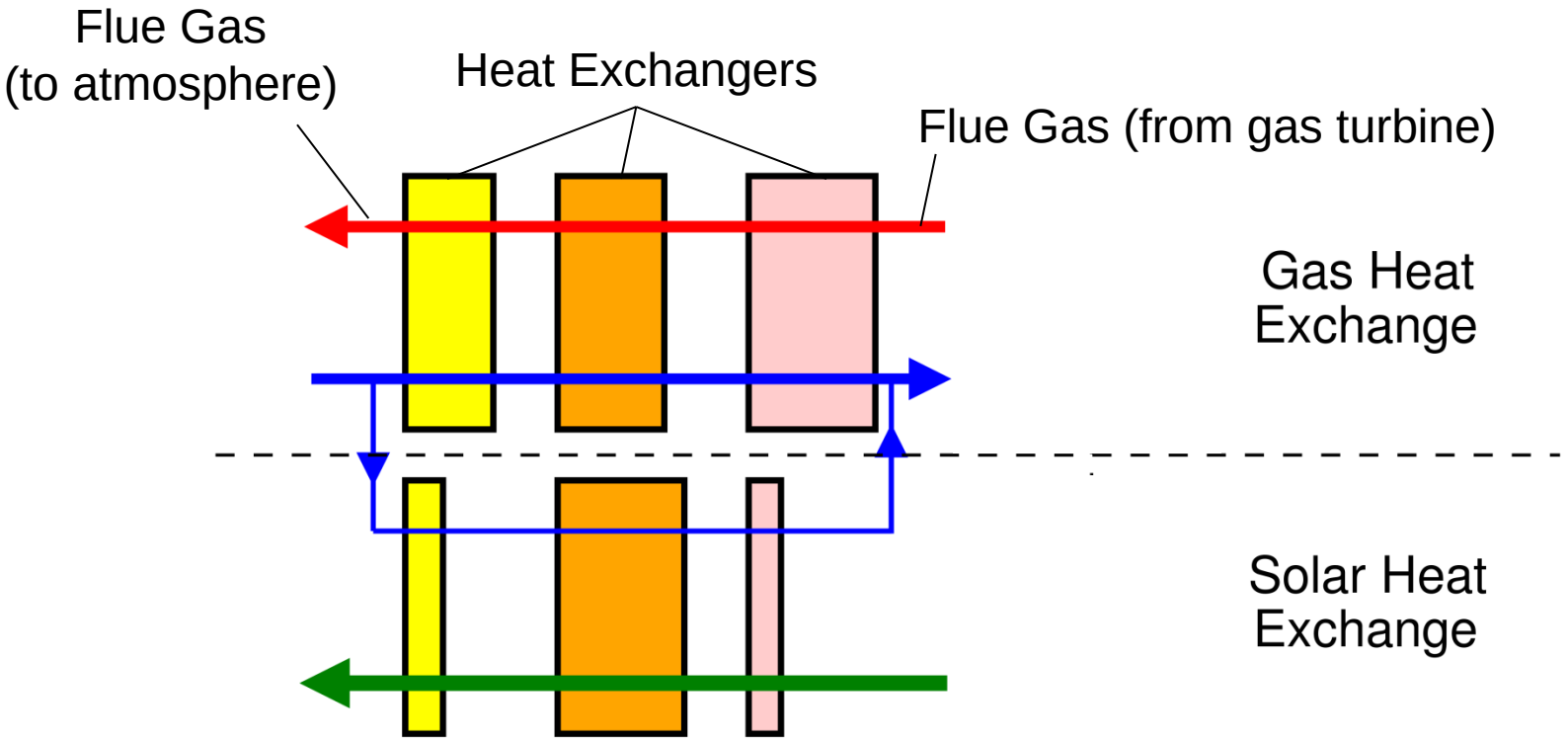
Hybrid System Overview



Module Details

- Solar thermal module:
  - Concentrating parabolic trough system
  - Therminol-VP1 as the heat transfer fluid
  - 10,000 m^2 facility
  - Based on data extracted from SAM
- Gas turbine module:
  - Based on modeled values for natural gas part-load performance [Kim, 2004]

Demonstration Configurations



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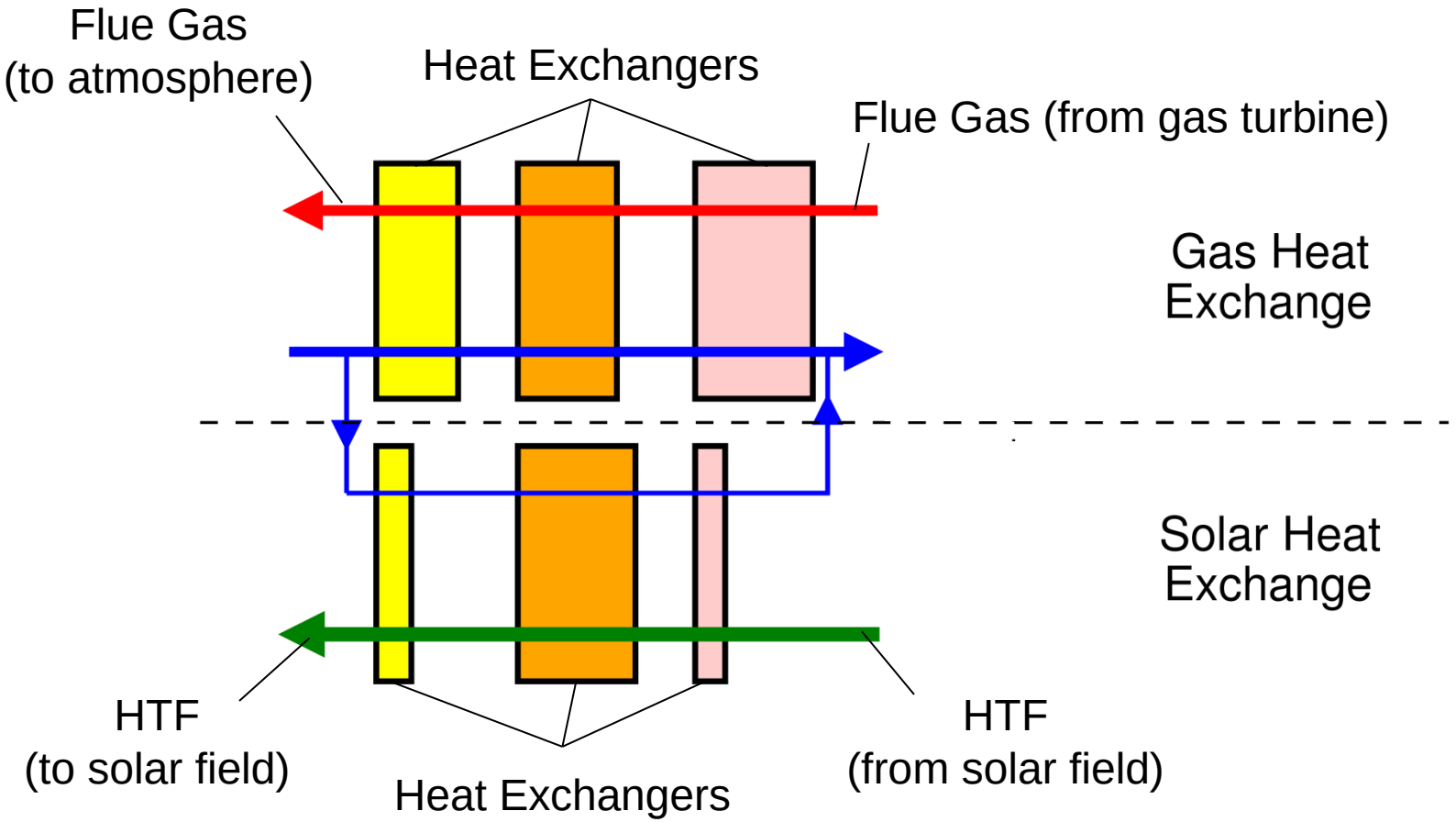

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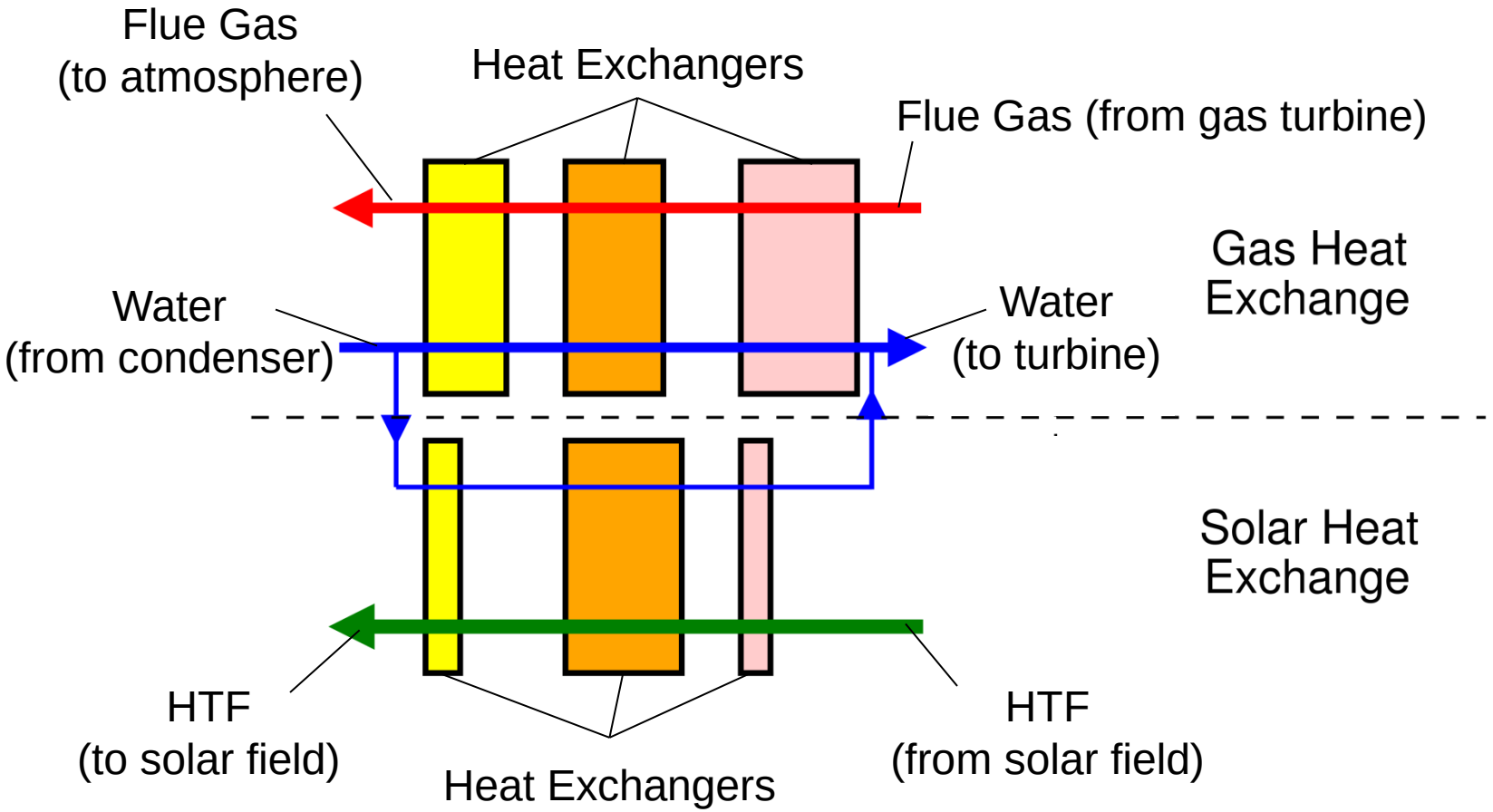

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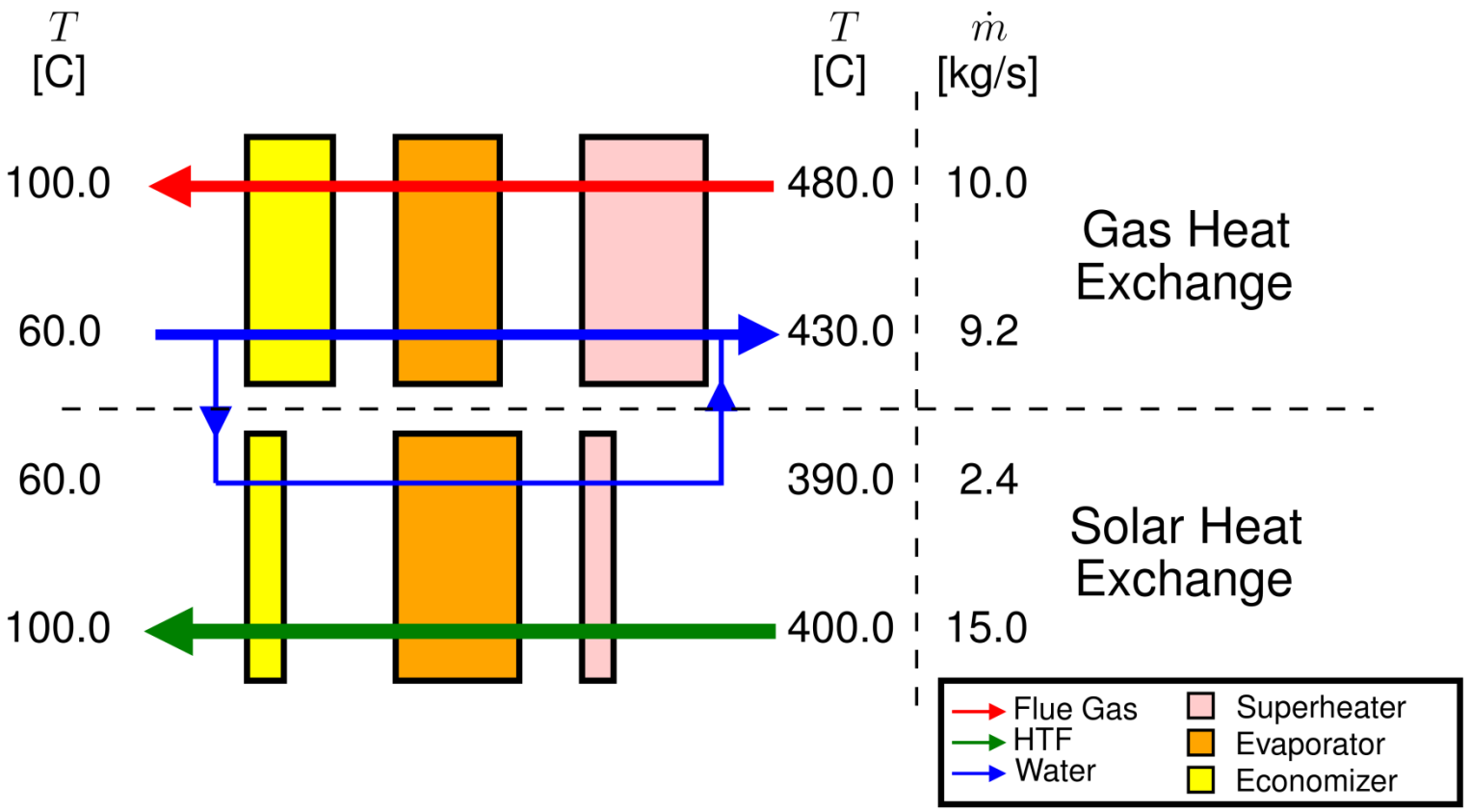

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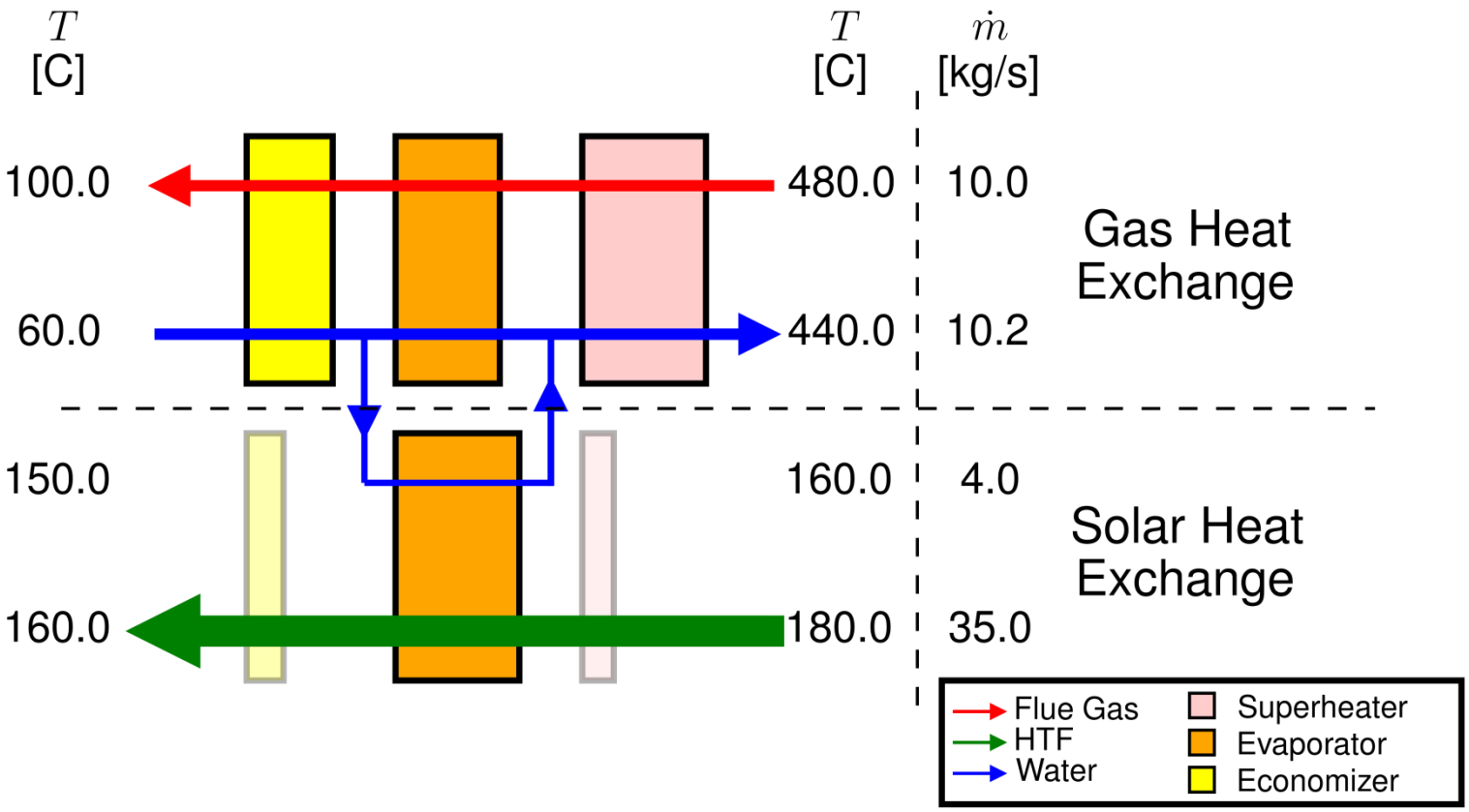


Proxy Model Motivation

- To optimize the hybrid system operations, a large number of configurations need to be evaluated (~10-100 million)
- Only one hour, not the entire year, is needed at each evaluation
- A smooth functional form is needed for derivative estimation inside of the system solution

Proxy Model

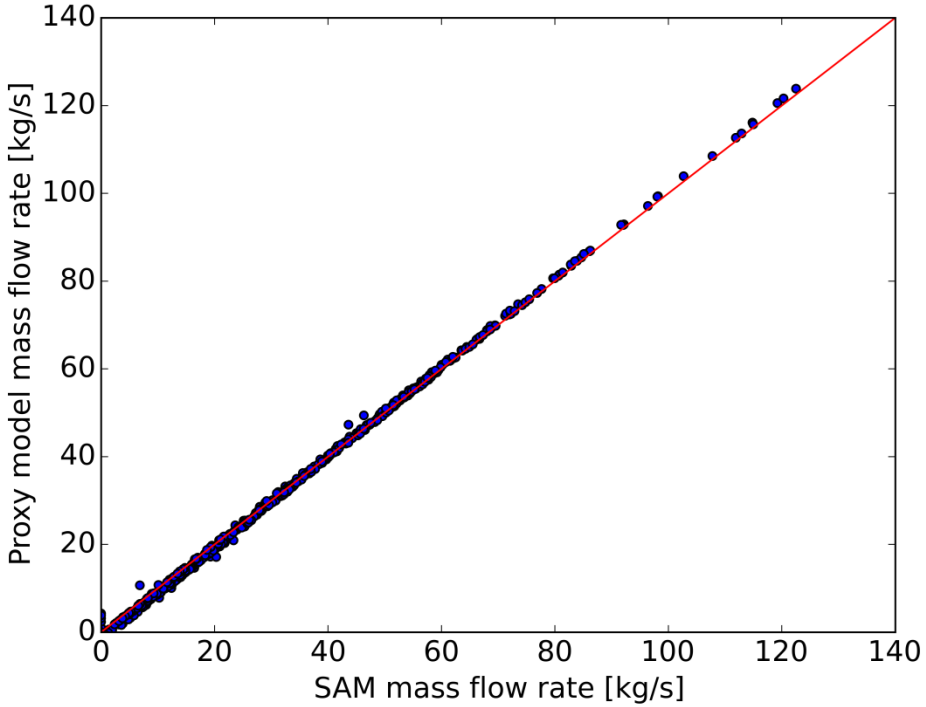
- For any given hour,

$$\dot{m} = \frac{c_0 - c_1 T_{out}}{T_{out} - T_{in}}$$

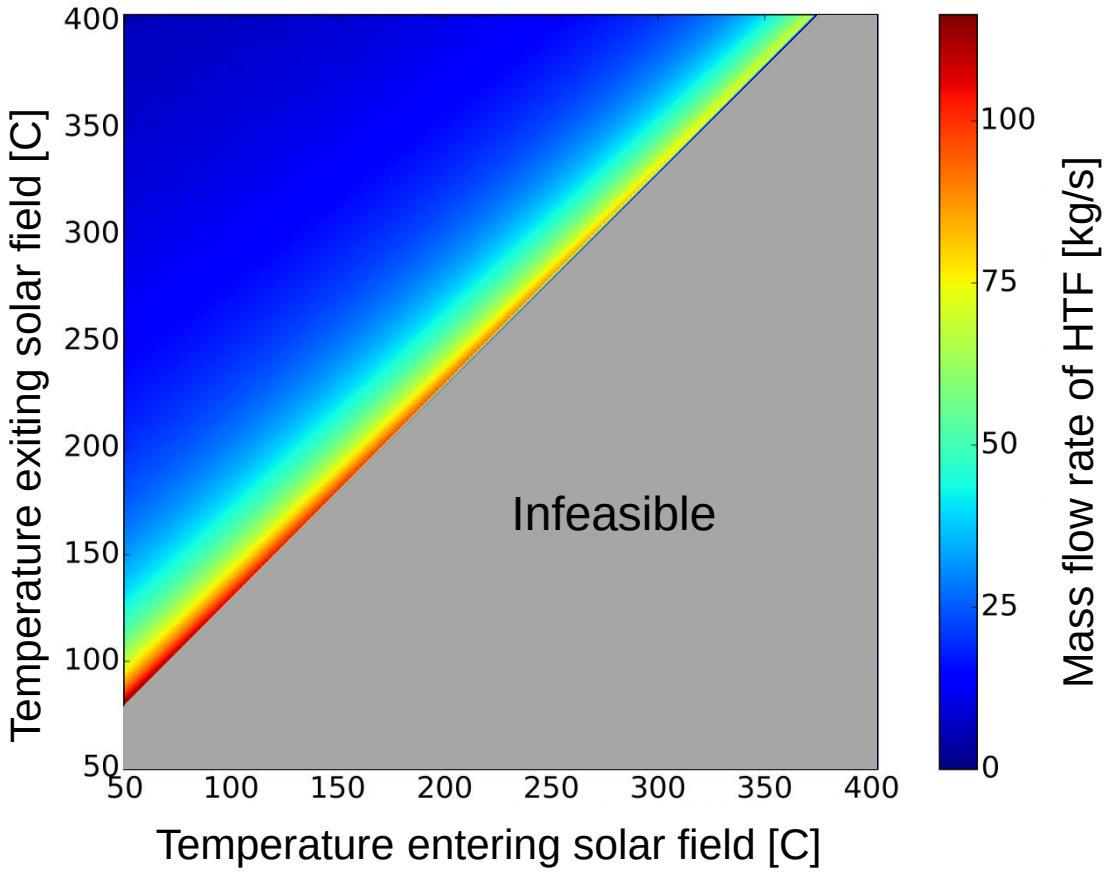
- T_{out} and T_{in} are the temperatures of the solar field at the inlet to and exit from the power block
- c_0 and c_1 are determined by a nonlinear least squares fit

Proxy Model Performance

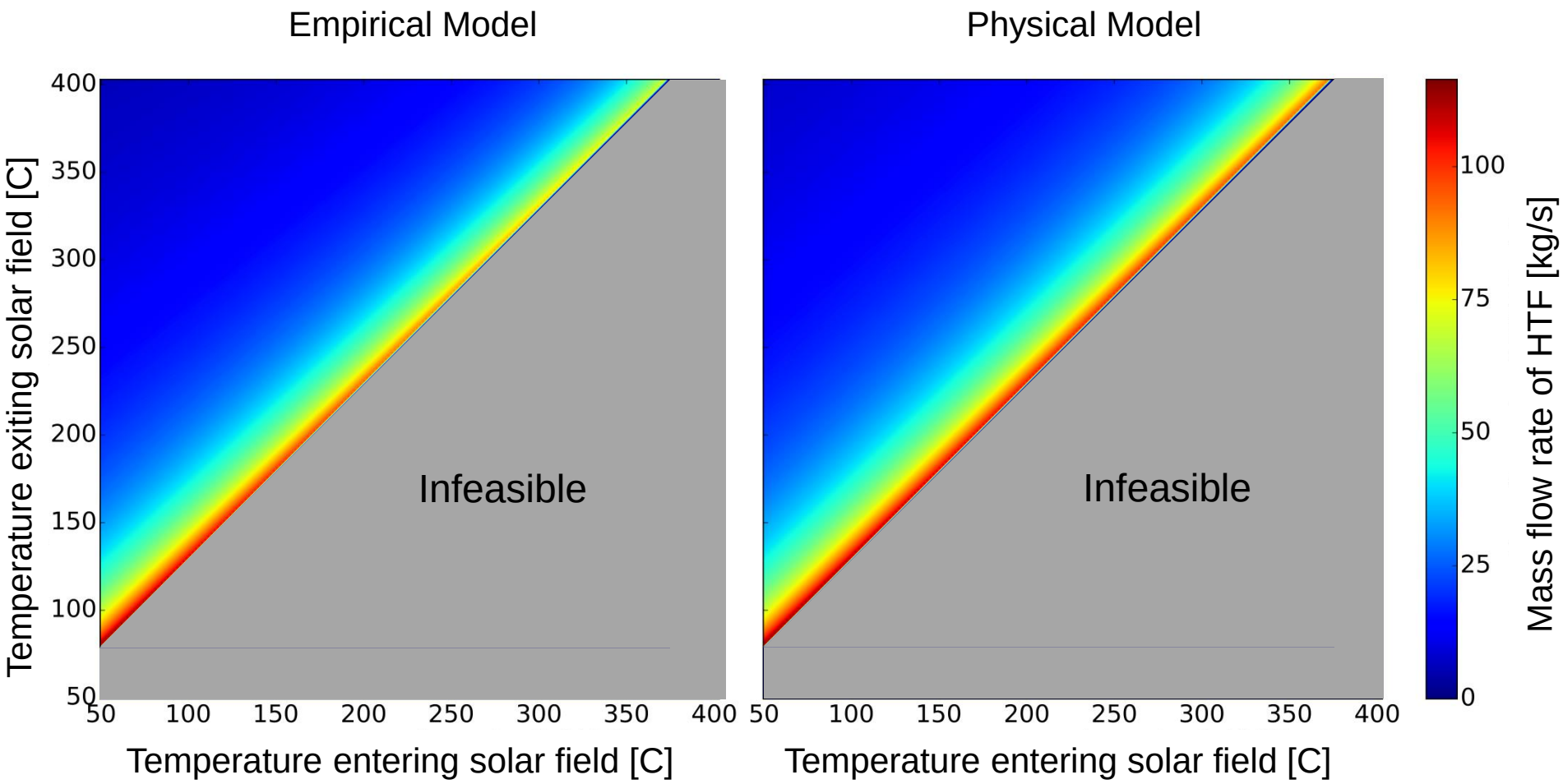
- Composite results from multiple hours
- SAM empirical model used
- Training set created on a fixed interval of points
- Test set created randomly
- RMSE = 0.68 kg/s
- Mean Abs. Error = 0.39 kg/s



Proxy Model Interpretation



Model Comparison



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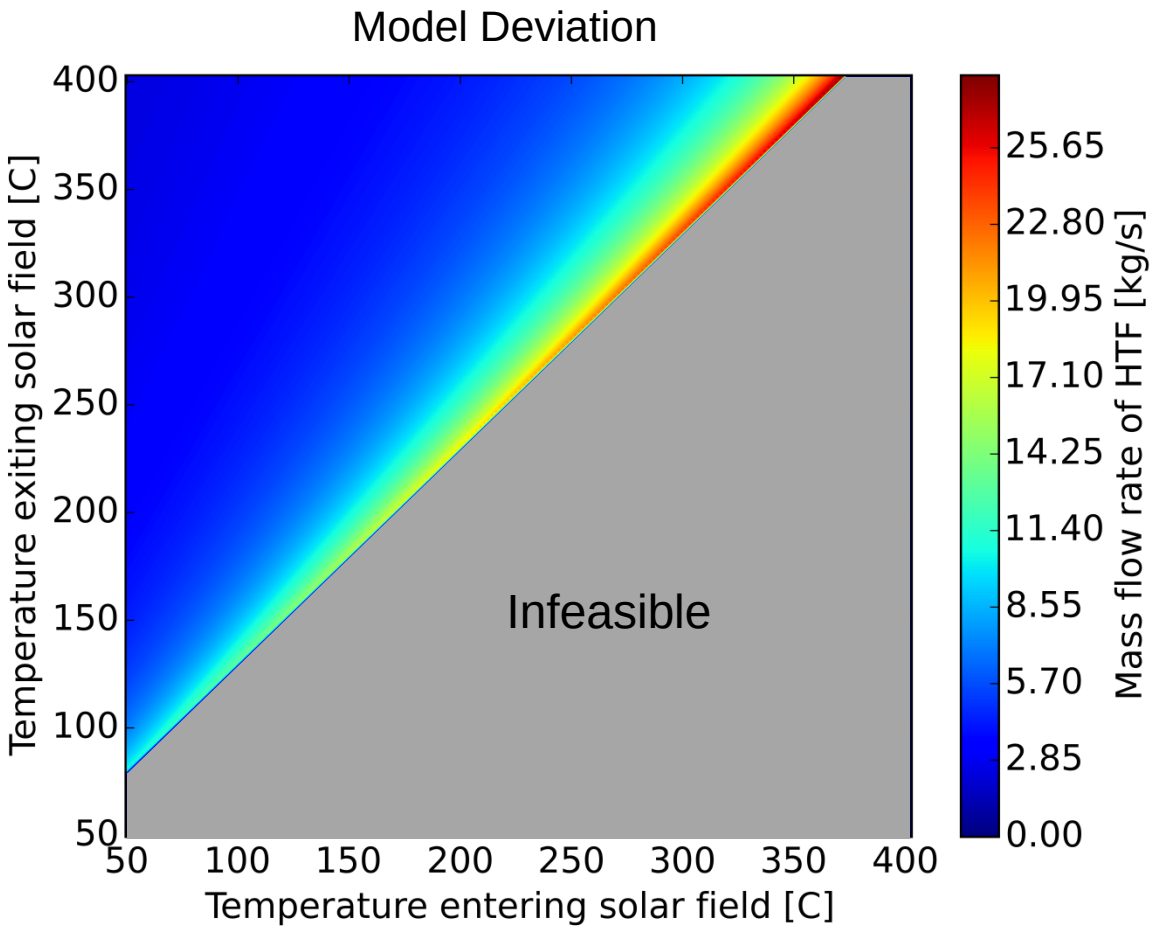

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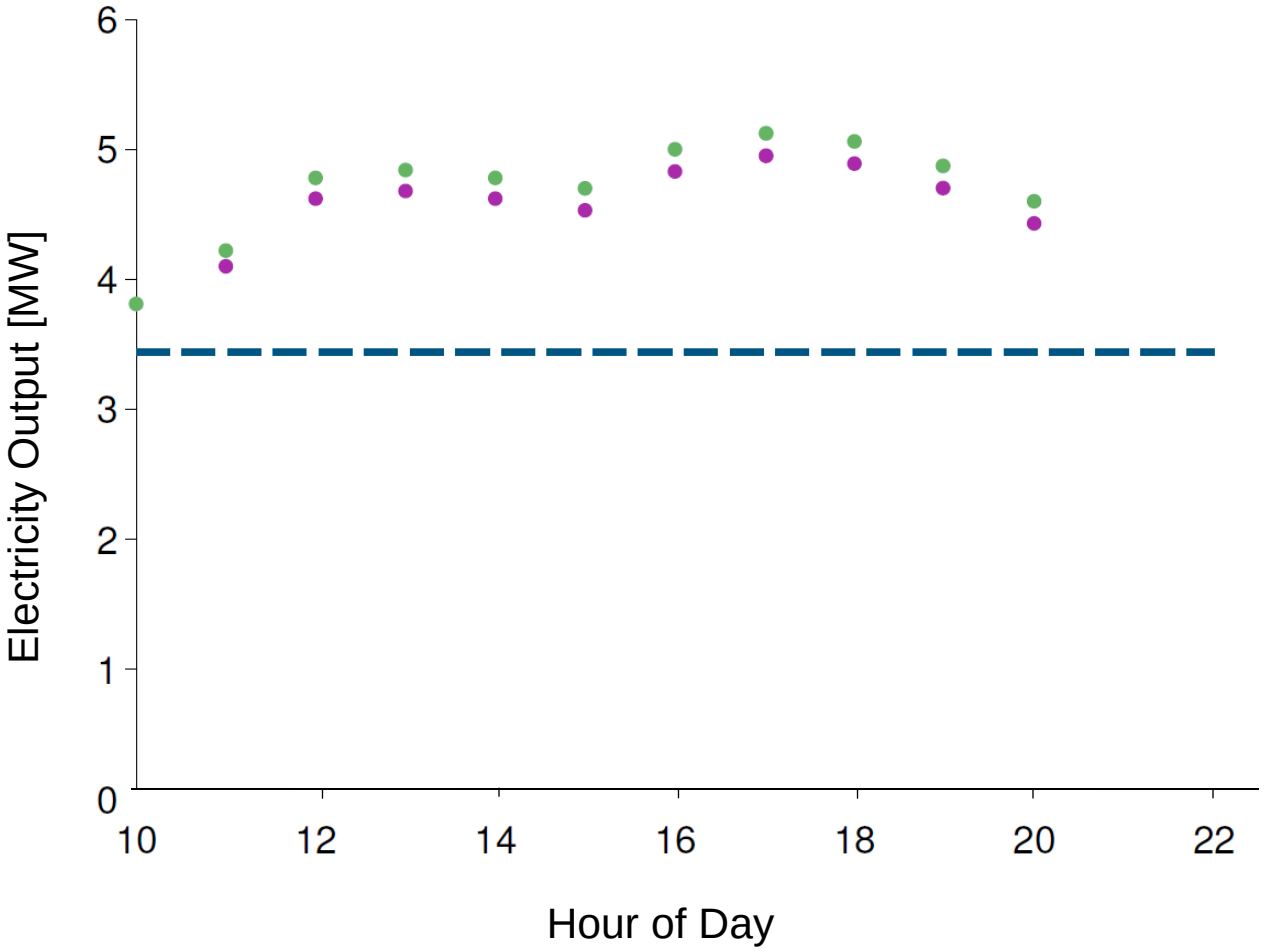
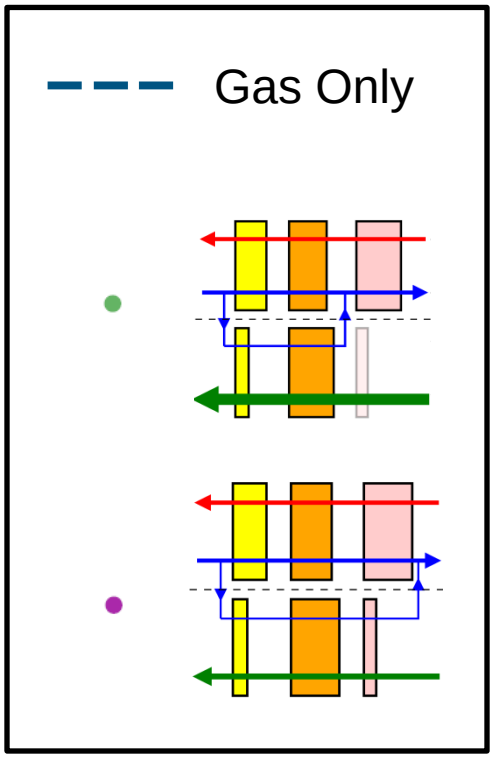
Preliminary Results

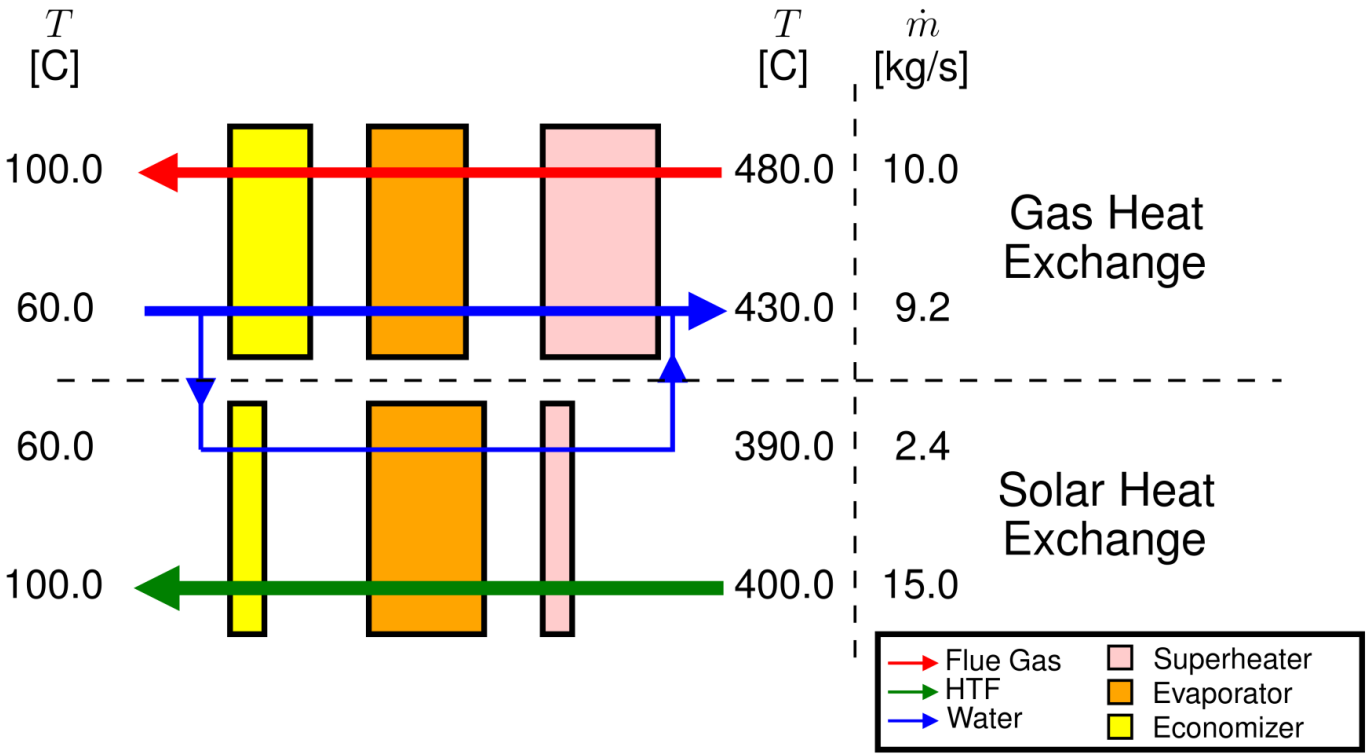




Conclusions / Future Work

- A model to evaluate different hybrid solar-gas operational configurations has been demonstrated
- A proxy model for SAM allows for fast system evaluations, while maintaining accuracy
- Different hybrid system configurations provide different electricity outputs
- Future work will explore optimal design and operations using this modeling approach

Questions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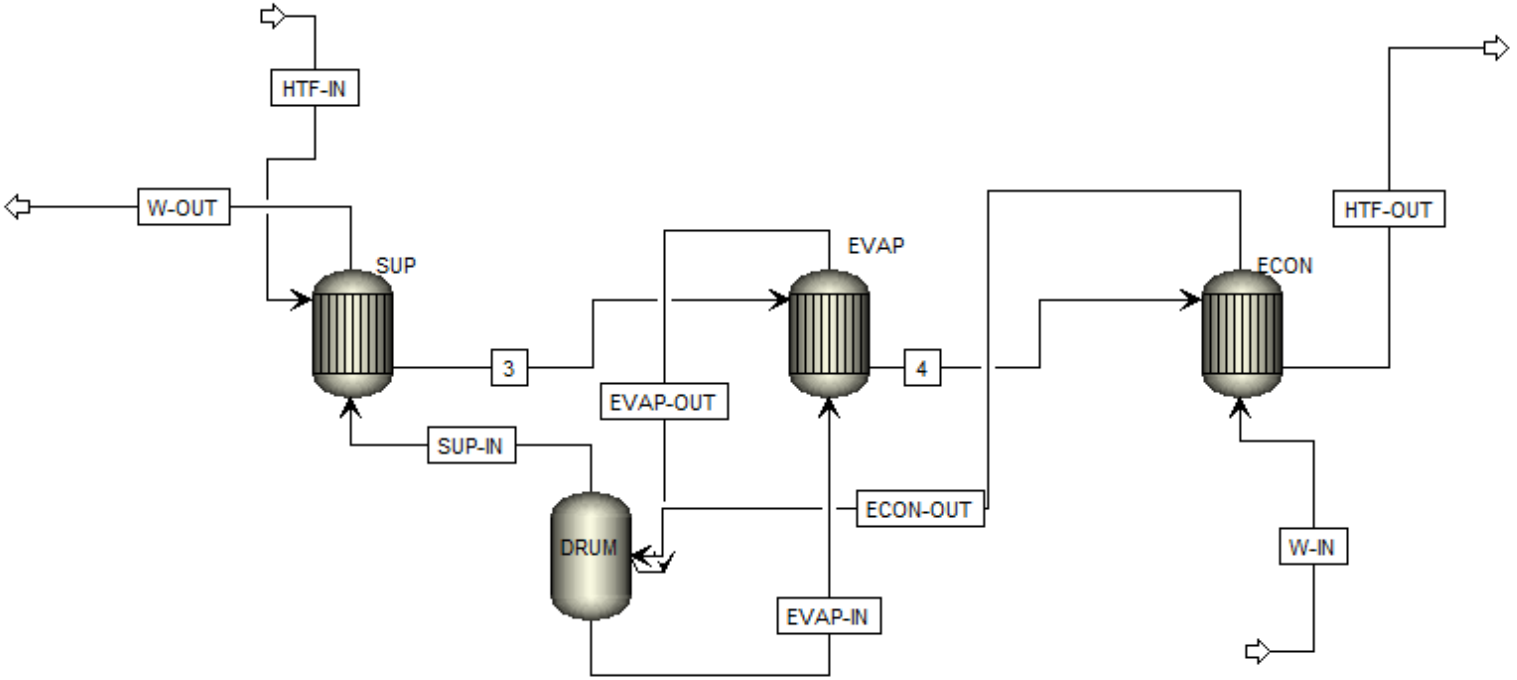
T
[C]
$\dot{m}$
[kg/s]
100.0
480.0
10.0
Gas Heat
Exchange
60.0
430.0
9.2
60.0
390.0
2.4
Solar Heat
Exchange
100.0
400.0
15.0
Flue Gas
HTF
Water
Superheater
Evaporator
Economizer

Validation of Heat Exchange with ASPEN Plus



Validation of Heat Exchange with ASPEN Plus

- Water and HTF inlet conditions and flow rates specified at ★
- Different configurations evaluated at ★
- Temperature and energy transfer at each point throughout the system agree with < 0.5% deviation